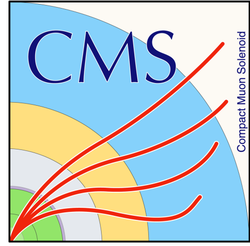
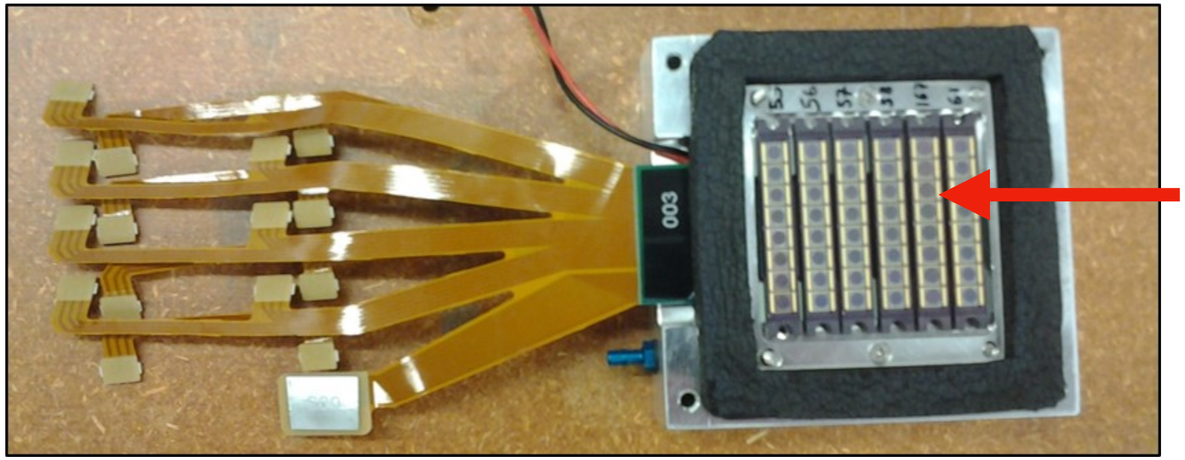


Phase-1 Upgrade of the CMS Hadron Calorimeter Endcaps

Caleb J. Smith (Baylor University)

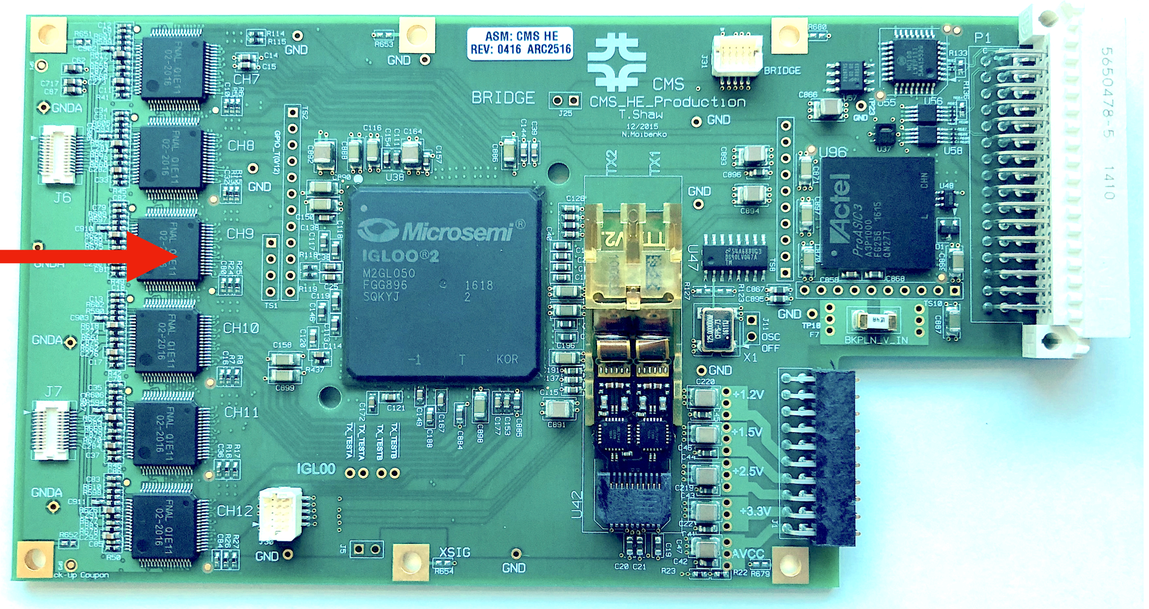
October 26, 2018

CMS HCAL Phase 1 Upgrade

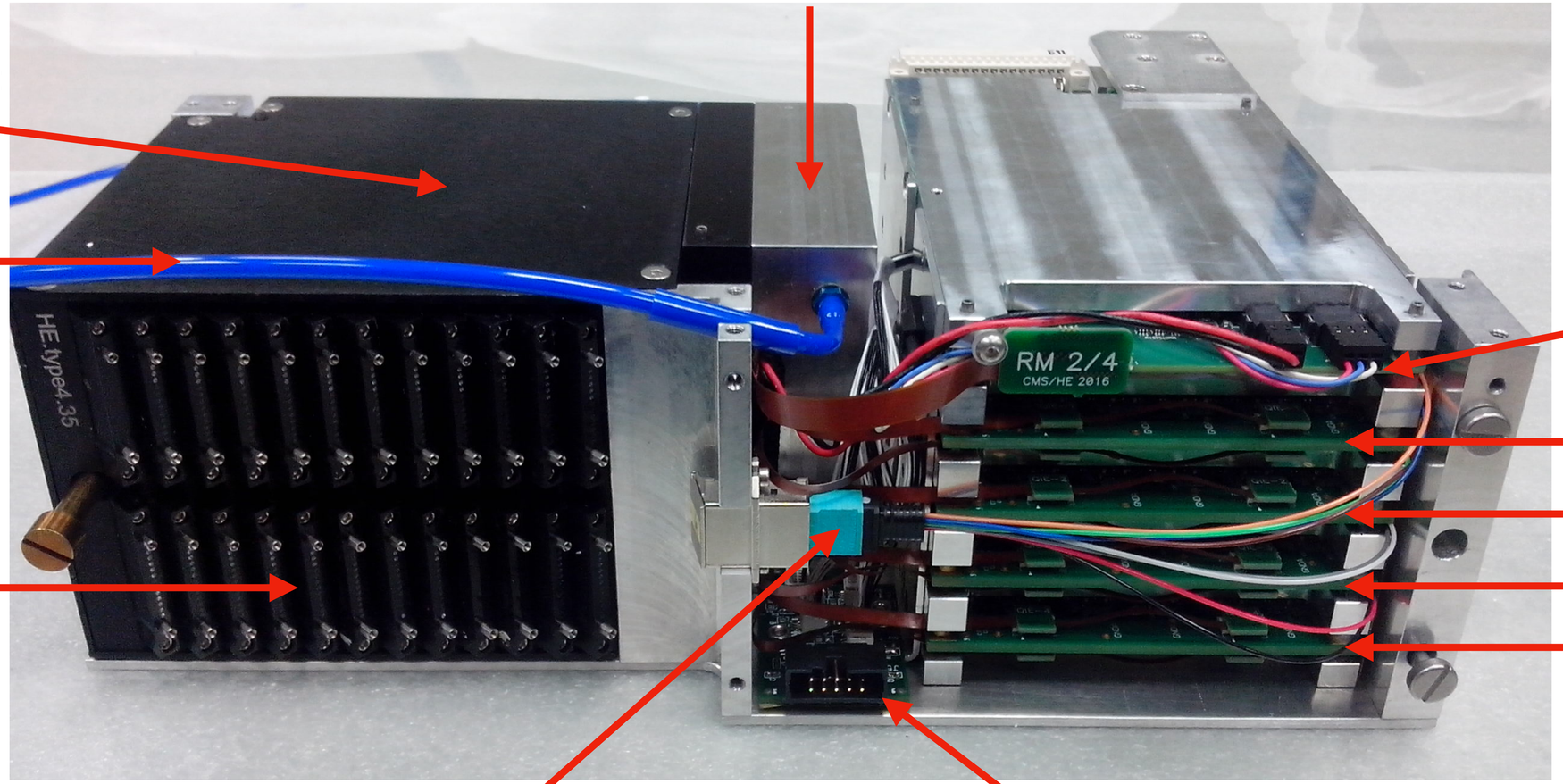


New photosensors
- Replace Hybrid Photo-Detectors (HPD) with Silicon Photomultipliers (SiPM)

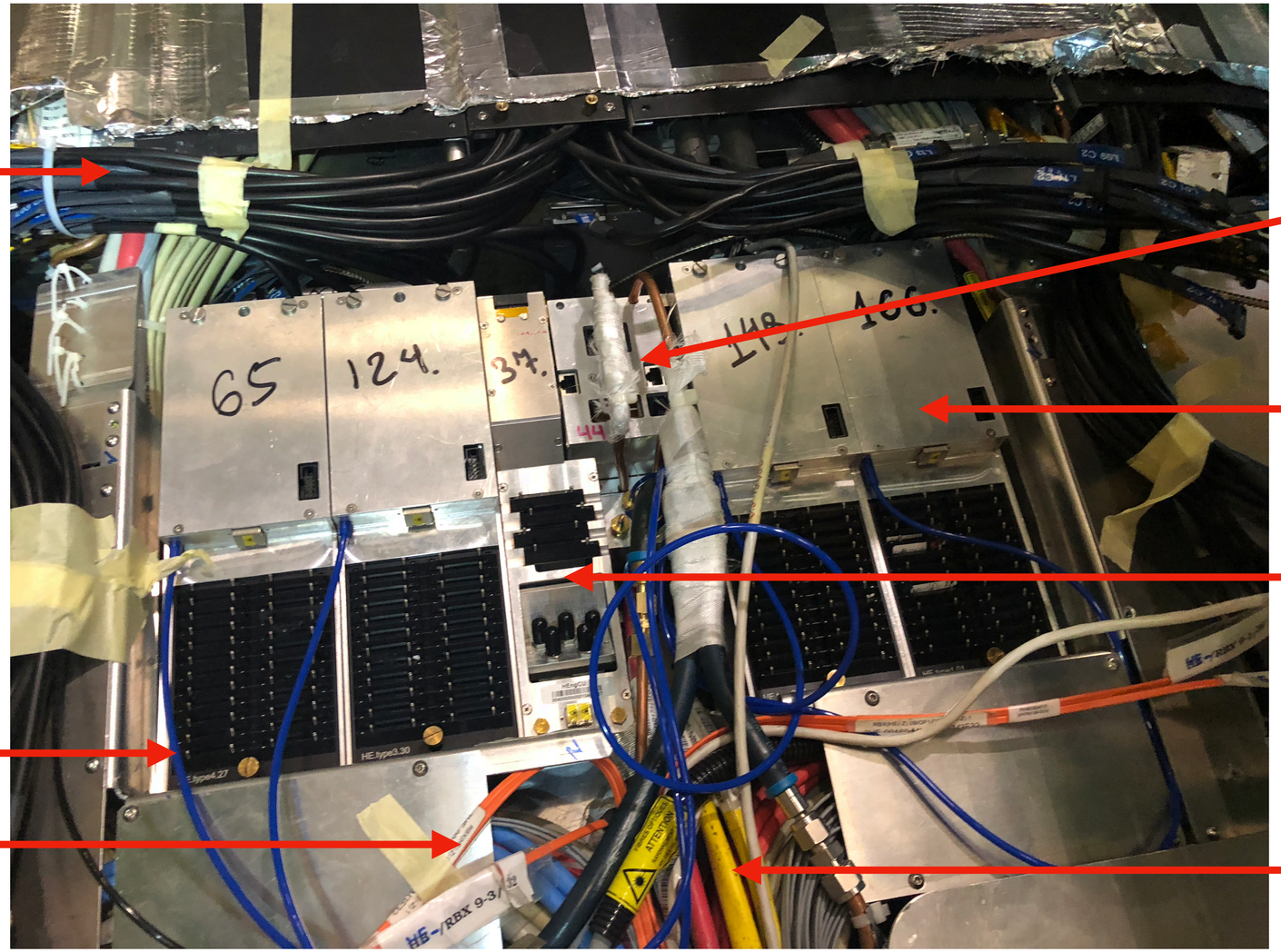
New readout electronics
- QIE cards with custom QIE ASIC chips



Phase 1 Readout Module (RM)

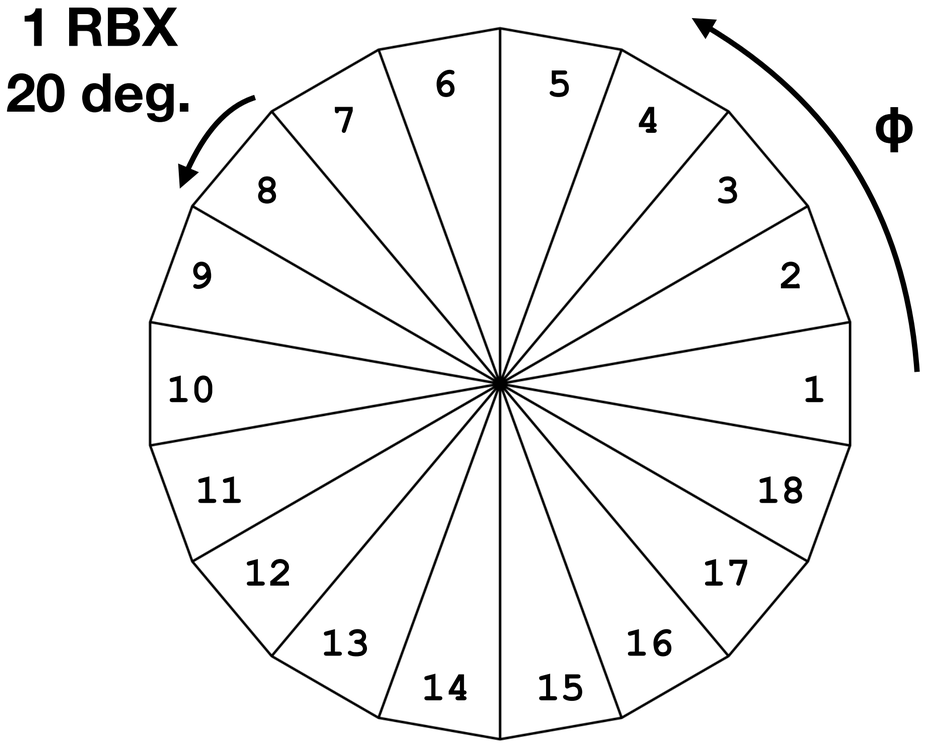


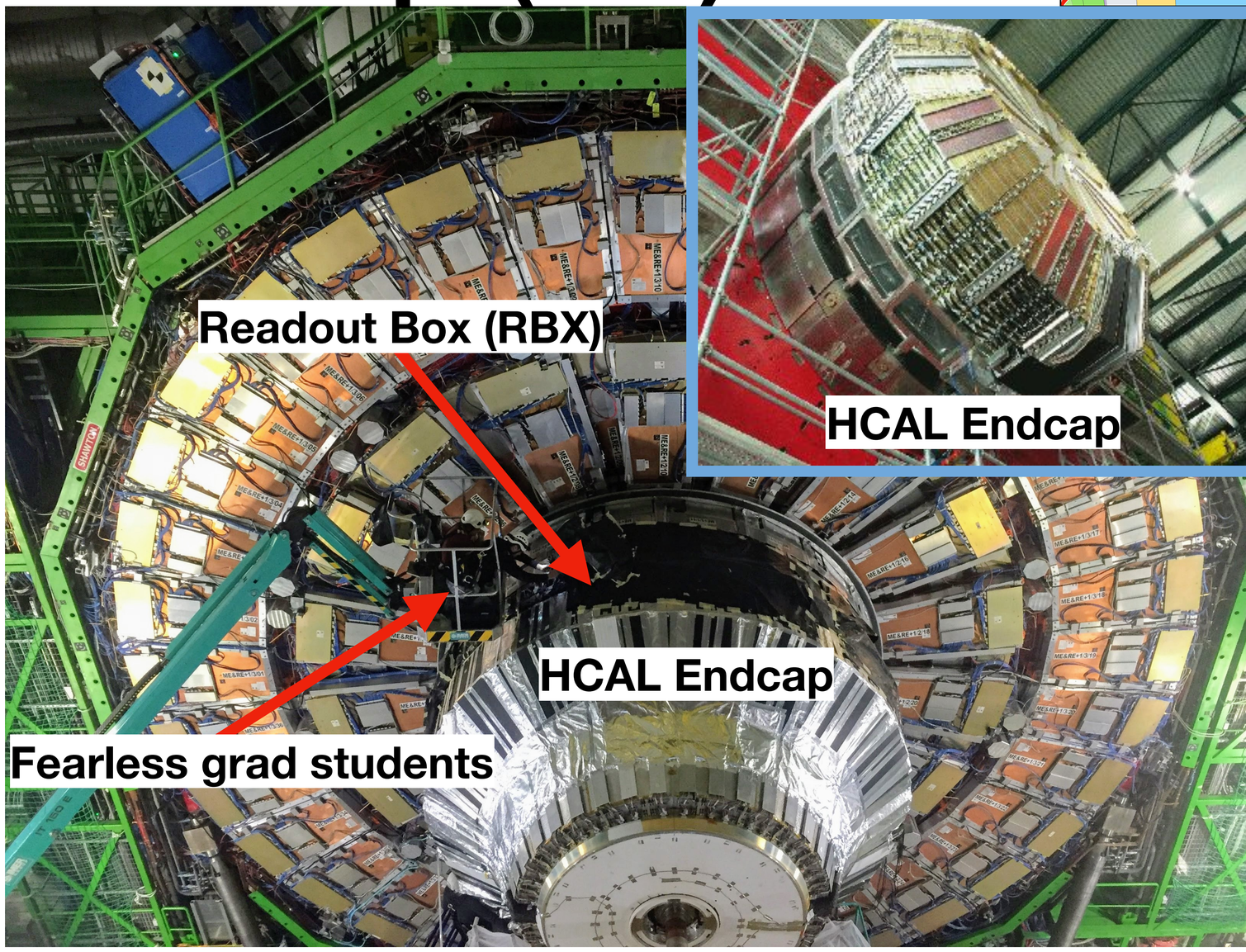
Phase 1 Readout Box (RBX)



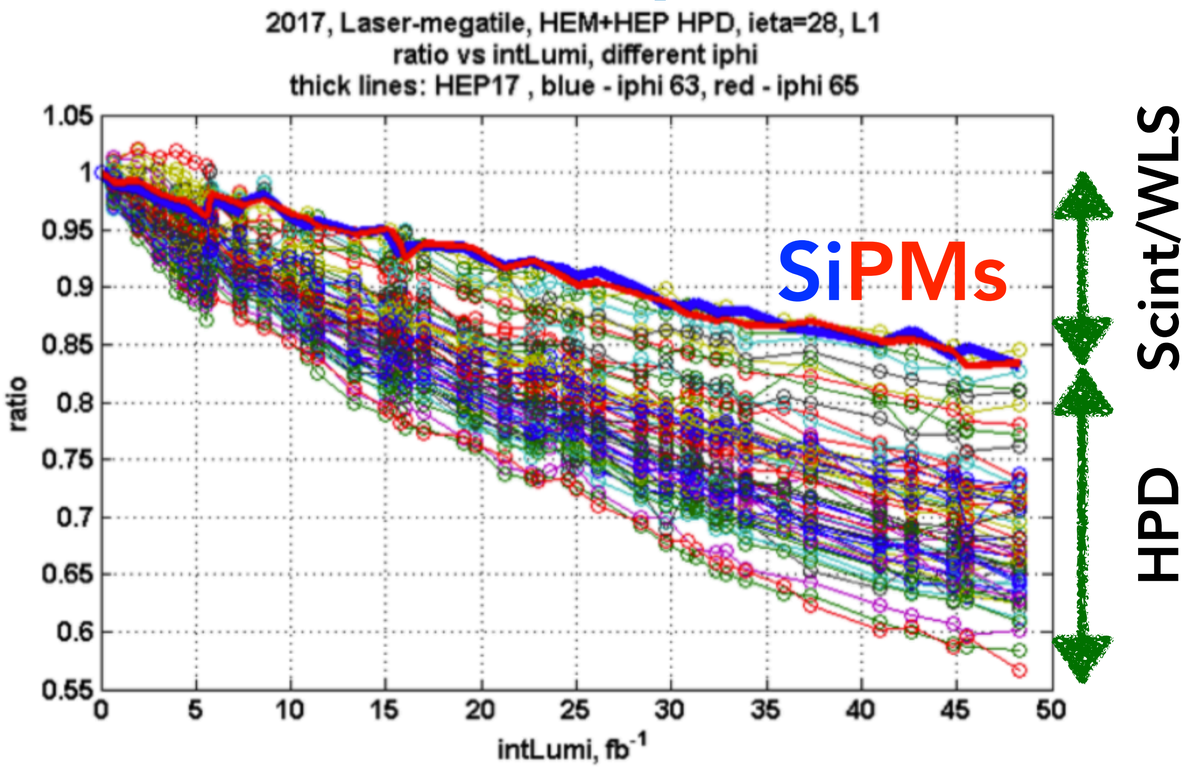
HCAL Endcap (HE)

- 2 HCAL Endcaps (± z)
- 18 wedges per Endcap
  - 1 Readout Box (RBX) per wedge
  - 20 deg. (ϕ) per wedge





Motivation



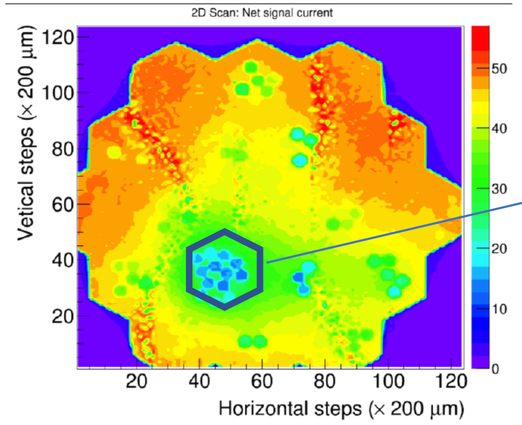
Response normalized to beginning of 2017

integrated luminosity (fb^{-1})

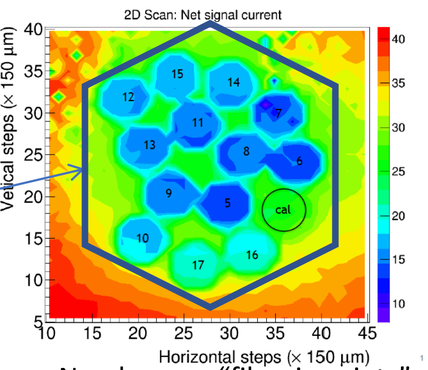
- Radiation damage to Hybrid Photo-Detectors (HPD) occurred sooner and was more severe than expected.
- The HE HPDs were replaced with SiPMs in the Phase 1 upgrade in early 2018.

HPD Radiation Damage

HPD from HEP17/RM4, Dec 2017



zoom into a single HPD pixel

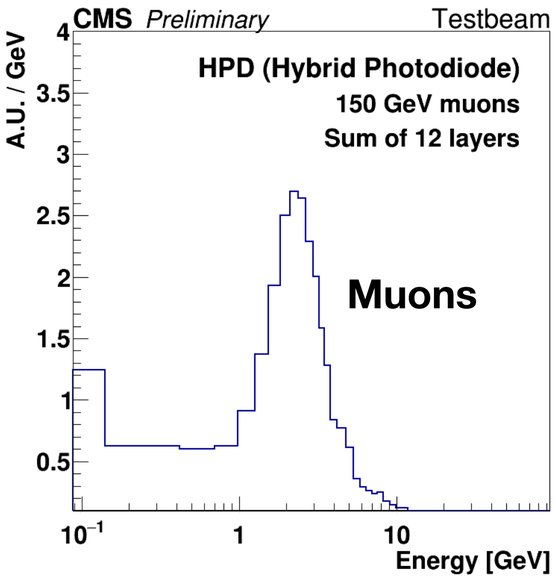


Numbers on “fiber imprints” indicate layer# of tile

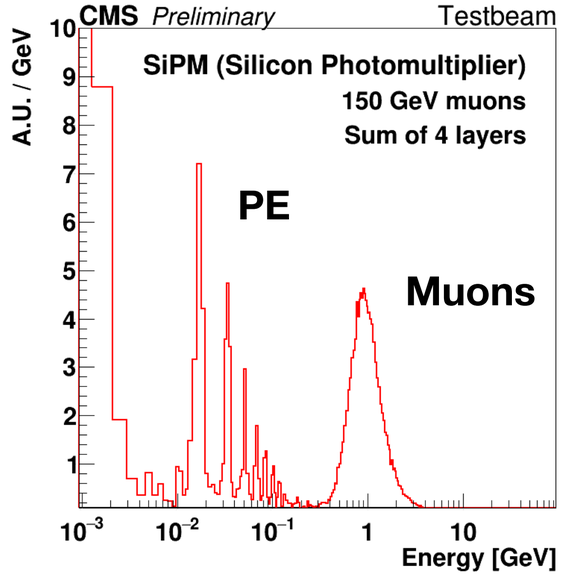
Talk: HCAL HE Status by Pawel De Barbaro

From HPDs to SiPMs

HPDs to SiPMs
- **x 400 higher gain**
- **x 2.5 PDE**
- **Lower voltage (8kV to 70V)**
- **Reduced noise**

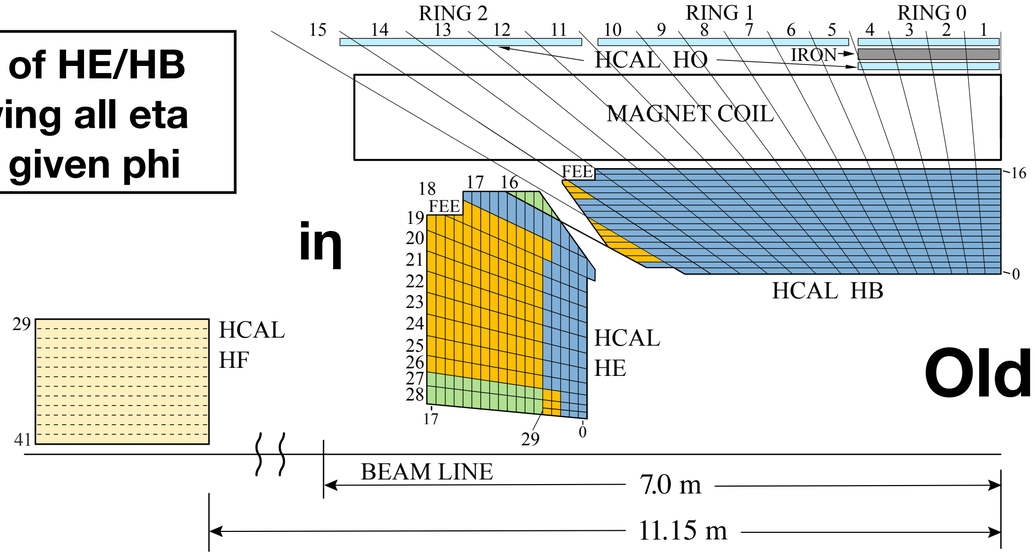


Calorimeter response to muons from HE prototype wedge at H2 beamline



New Geometry

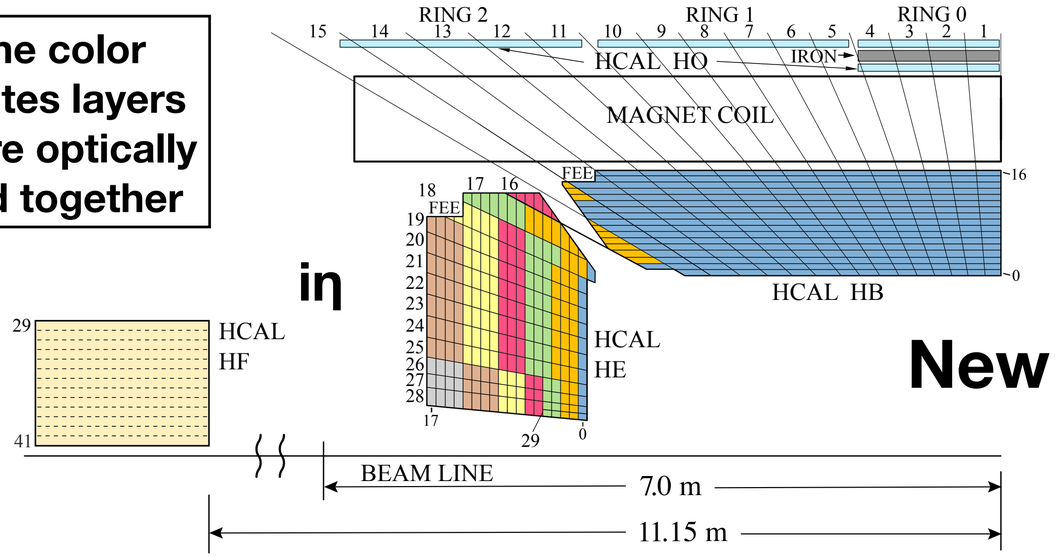
Slice of HE/HB showing all eta for a given phi



Old geometry

- Increase in number of channels.
- Increase in number of depths (each color is a depth).
- Provides better longitudinal segmentation.

Same color indicates layers that are optically added together

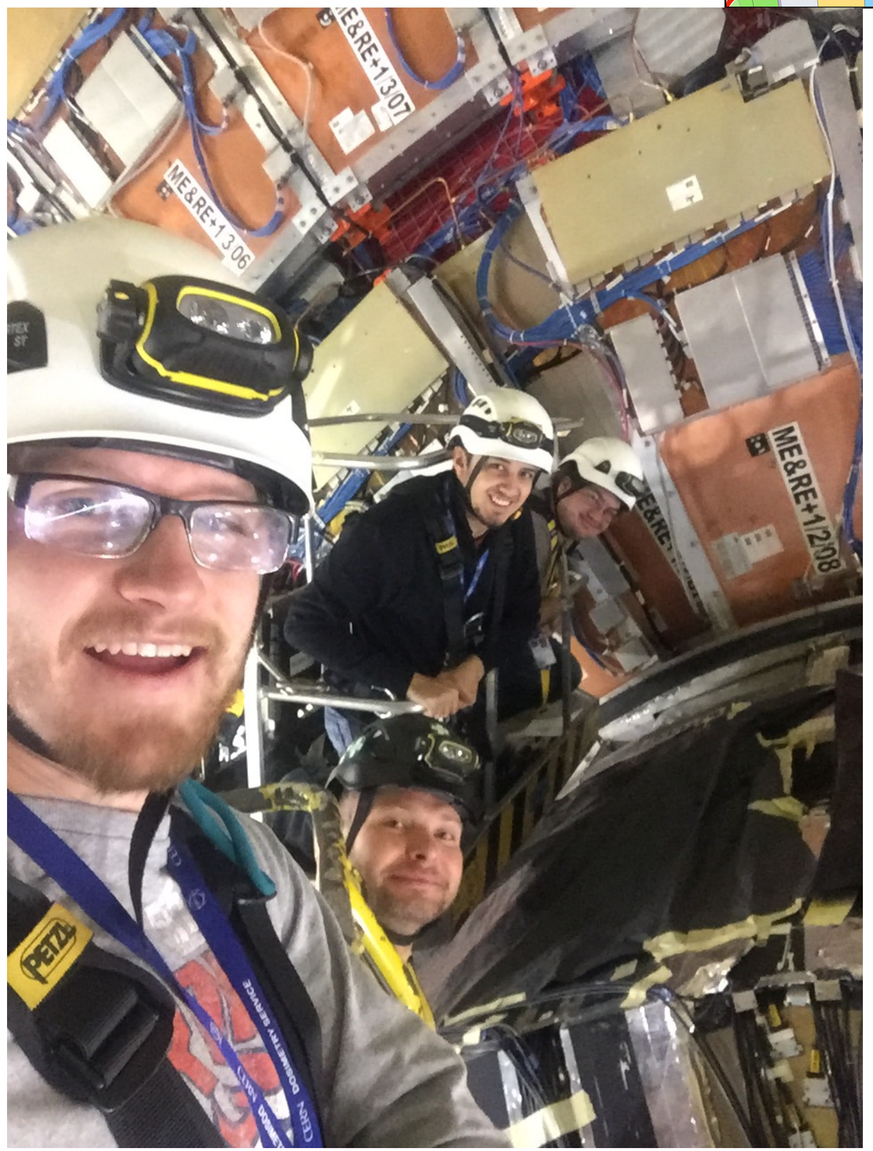


New geometry

Installation

Procedure

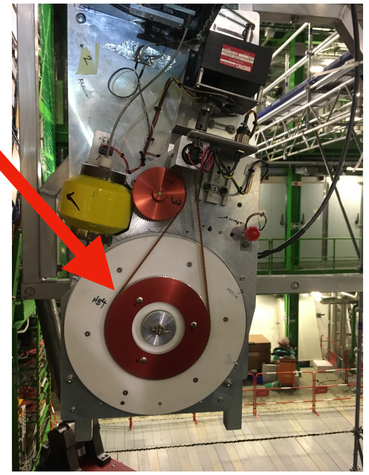
- Remove existing electronics.
- Install new electronics.
- Test control and data links.
- Take FiberID, LED, and Laser data.
- Perform radiation sourcing scan with Co60.
- Calibrate using Co60 data.



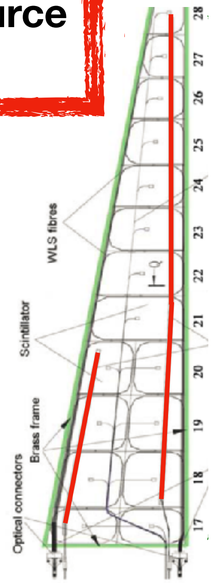
Commissioning with Co60

- Radioactive source (Co60) is pushed with a wire through tubes in the detector.
- As the wire extends, the source passes near different scintillator tiles.
- Response measured in every channel.
- Used to verify end-to-end channel mapping and cable connections.
- Used for startup calibration of detector.

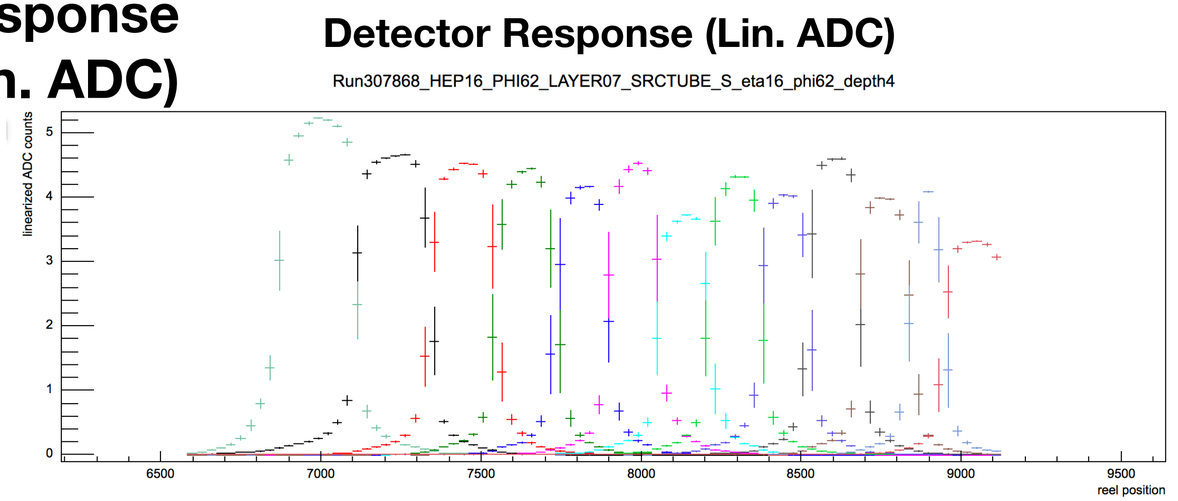
Source Driver



Radioactive Source on wire

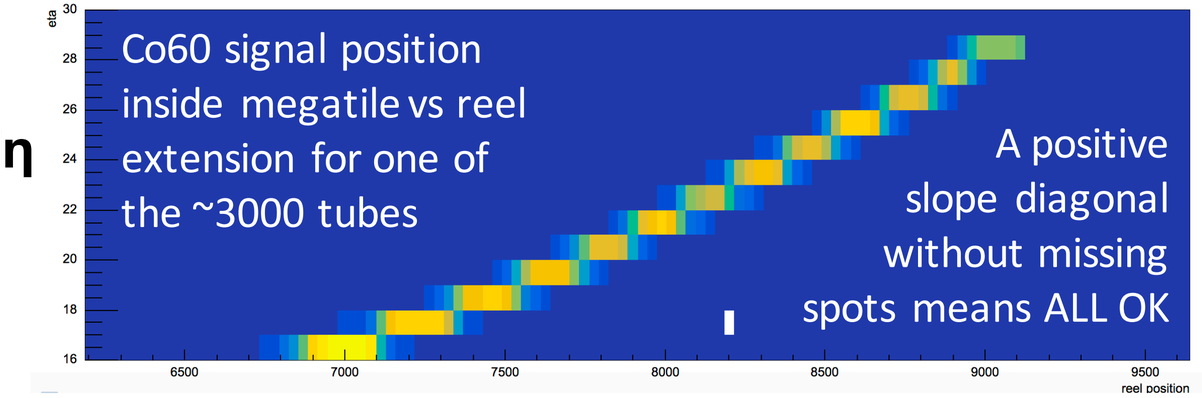


Response (Lin. ADC)



Wire extension (mm)

iη

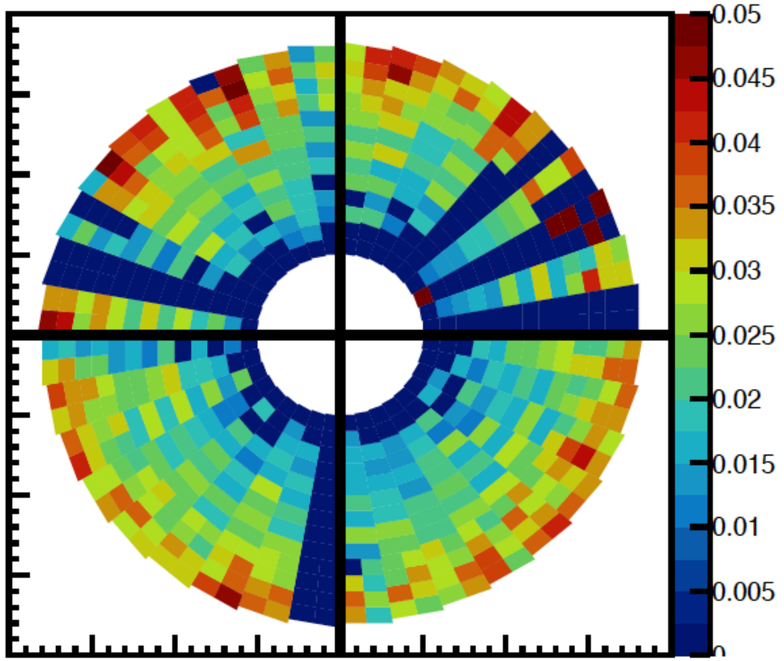


Wire extension (mm)

Commissioning with Co60

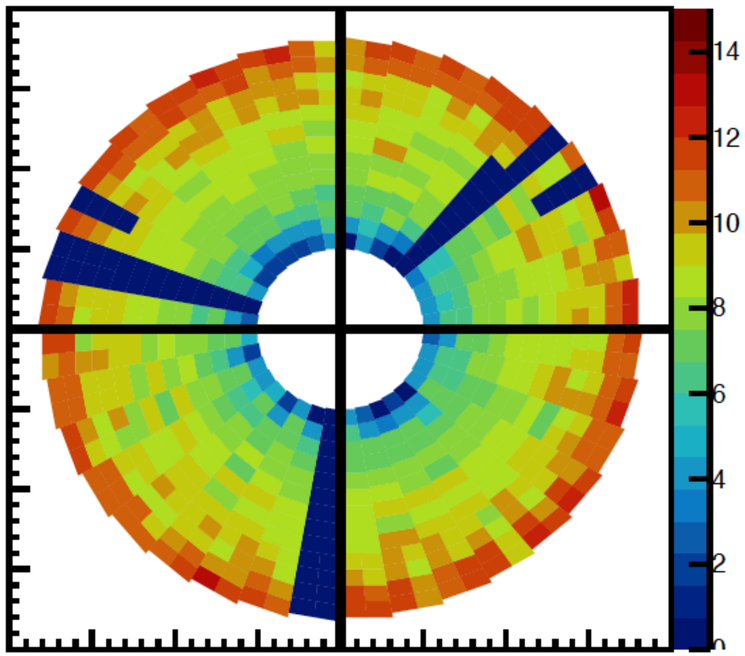
Before upgrade → After upgrade

HEP Layer 1



2017 sourcing (HPD)

HEP Layer 1

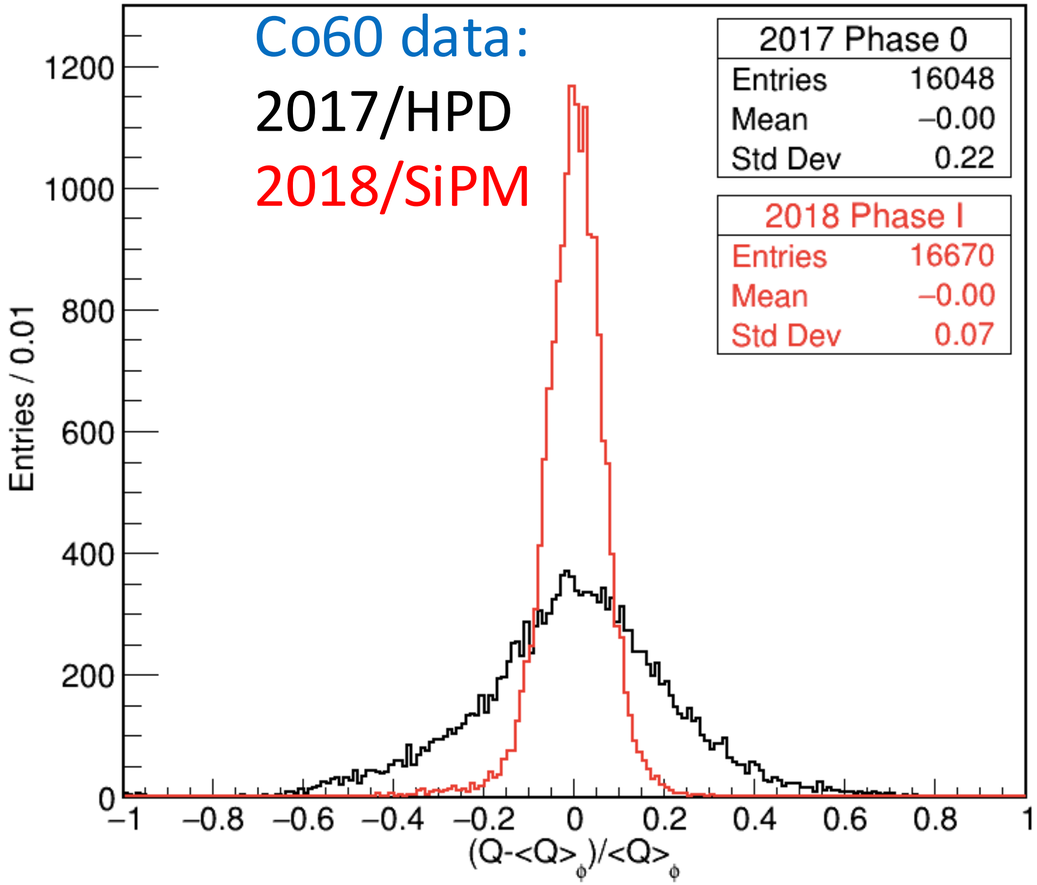


2018 sourcing (SiPM)

Improved uniformity vs. phi after the upgrade!

Commissioning with Co60

100 * Entries



(Charge - Mean) / Mean

- Comparison of 2017 sourcing (HPD) and 2018 sourcing (SiPM).
- Improved uniformity in 2018.

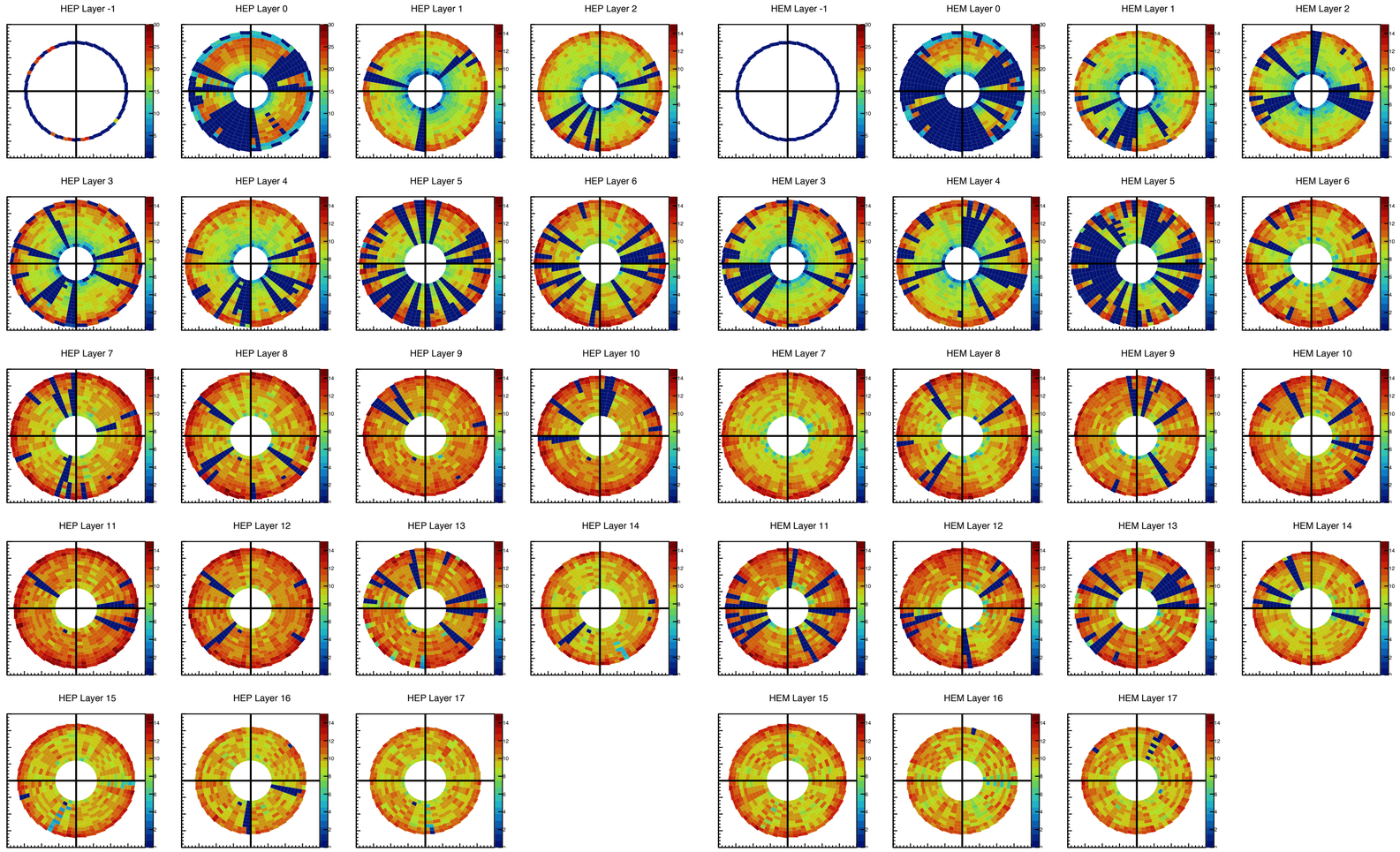
Conclusion

- Installation and commissioning were completed on schedule during the 2017–18 year-end technical stop.
- The HE Phase 1 upgrade brings improved detector response and uniformity.
- The HCAL Barrel (HB) Phase 1 upgrade will be installed during Long Shutdown 2 (2019–2020).

Thank you for your time!

Backup

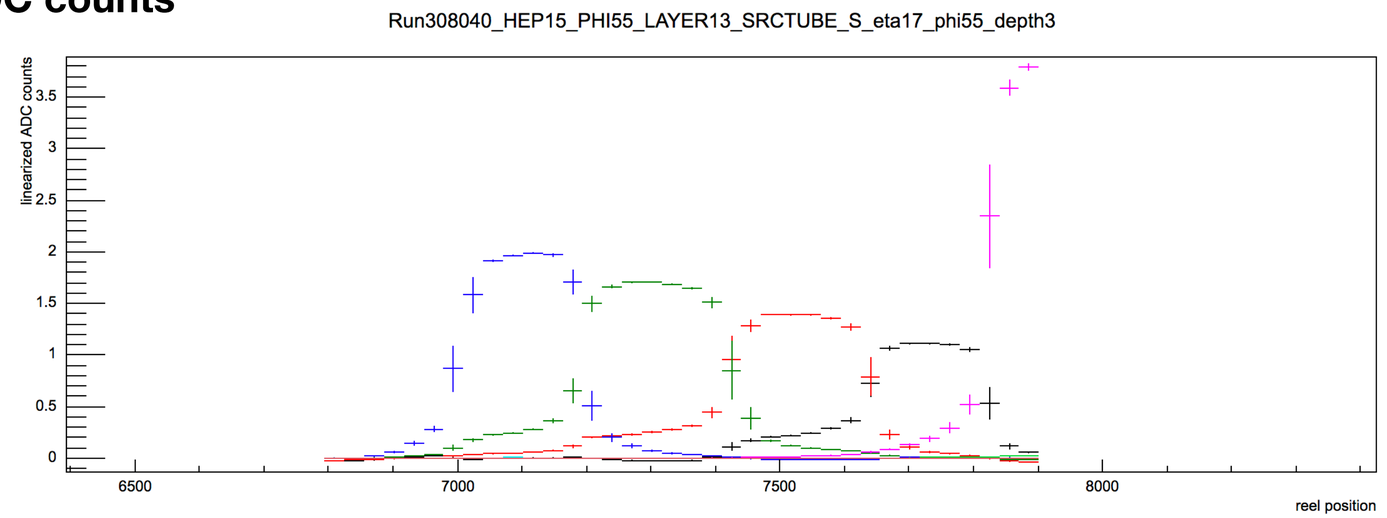
Commissioning with Co60



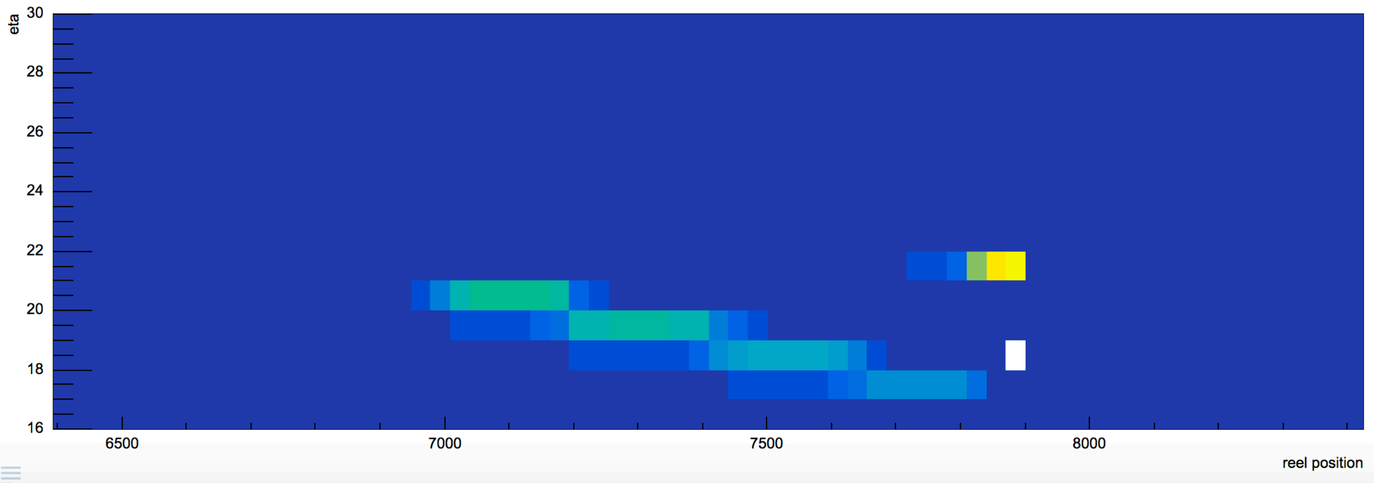
- http://feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEP.pdf
- http://feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEP_2017.pdf
- http://feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEM.pdf
- http://feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEM_2017.pdf

Commissioning with Co60

Lin. ADC counts



iη

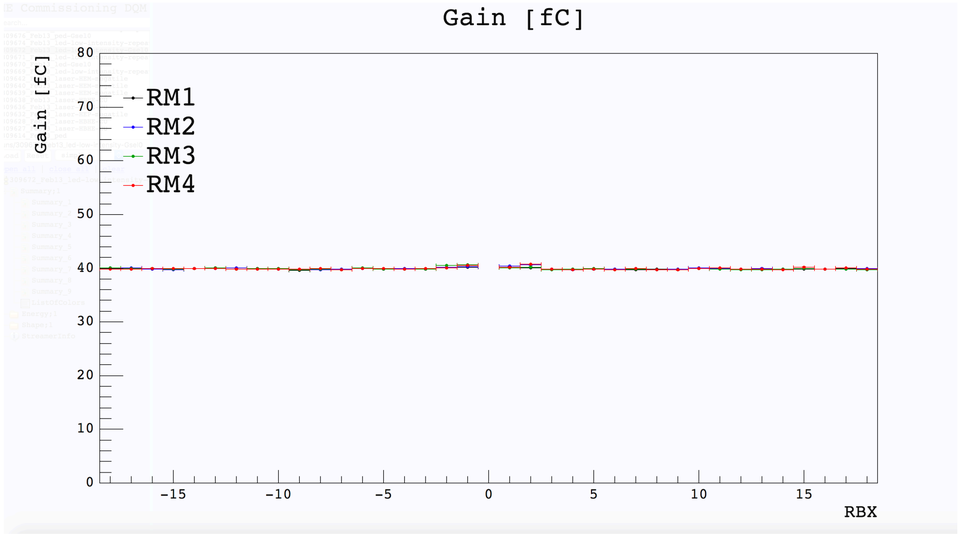


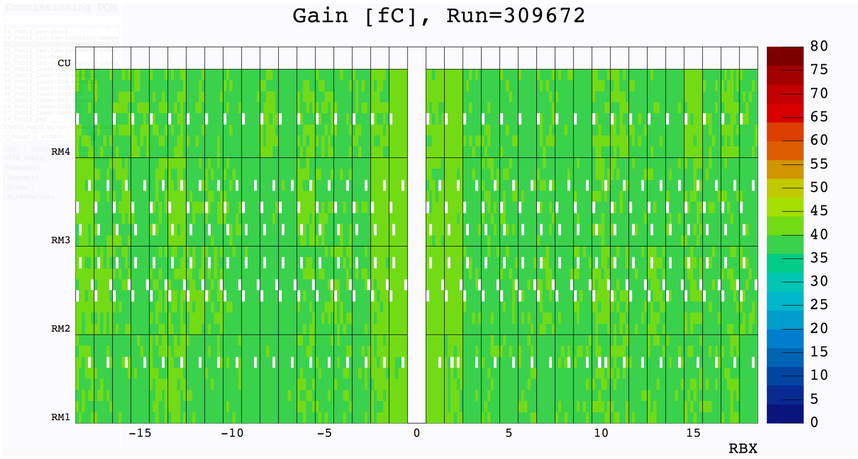
Reel position (mm)

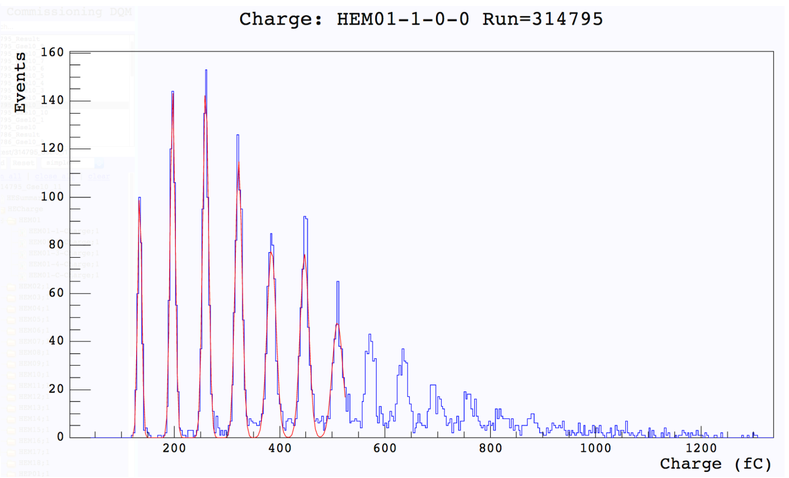
- Megatile cable is connected backwards

Commissioning with LED

- Low intensity LED runs were used to tune the SiPM gains.
- The bias voltages are selected such that the gains are tuned to 40 fC (charge measured for one electron).

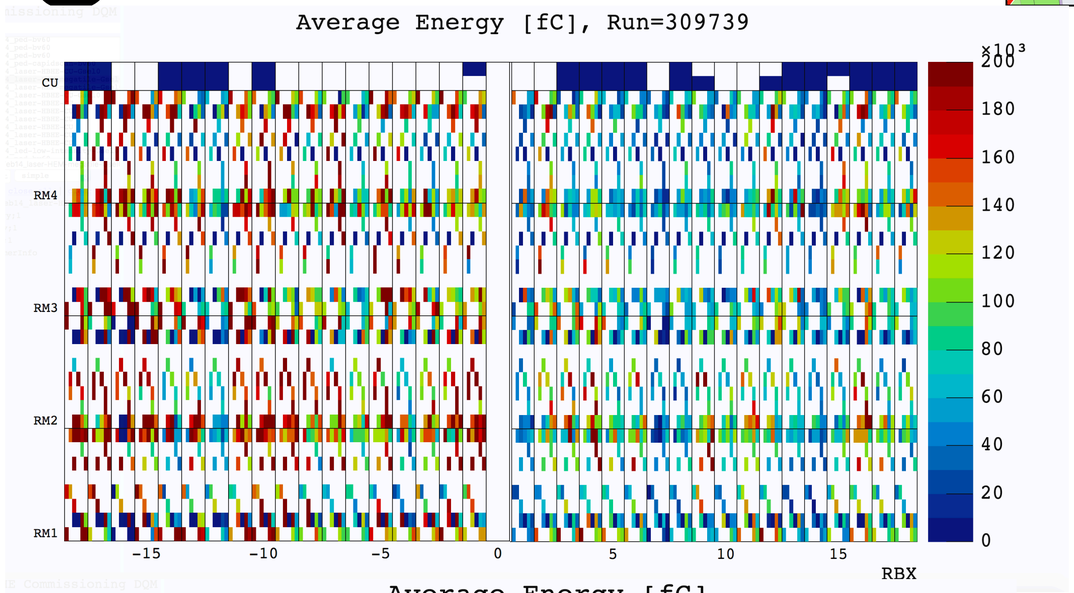




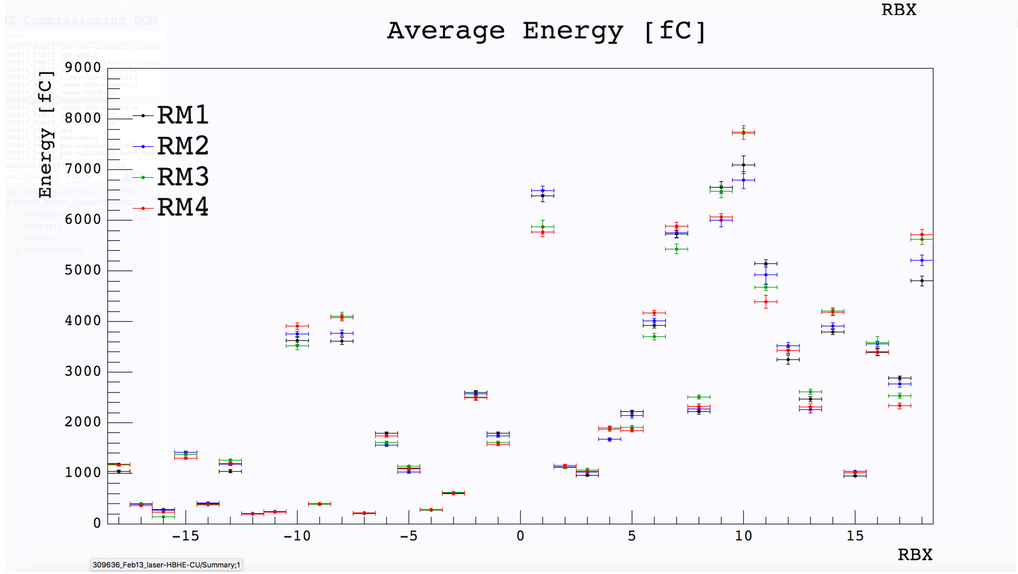


Commissioning with Laser

- Laser to Megatile
  - Only measured by a subset of channels.

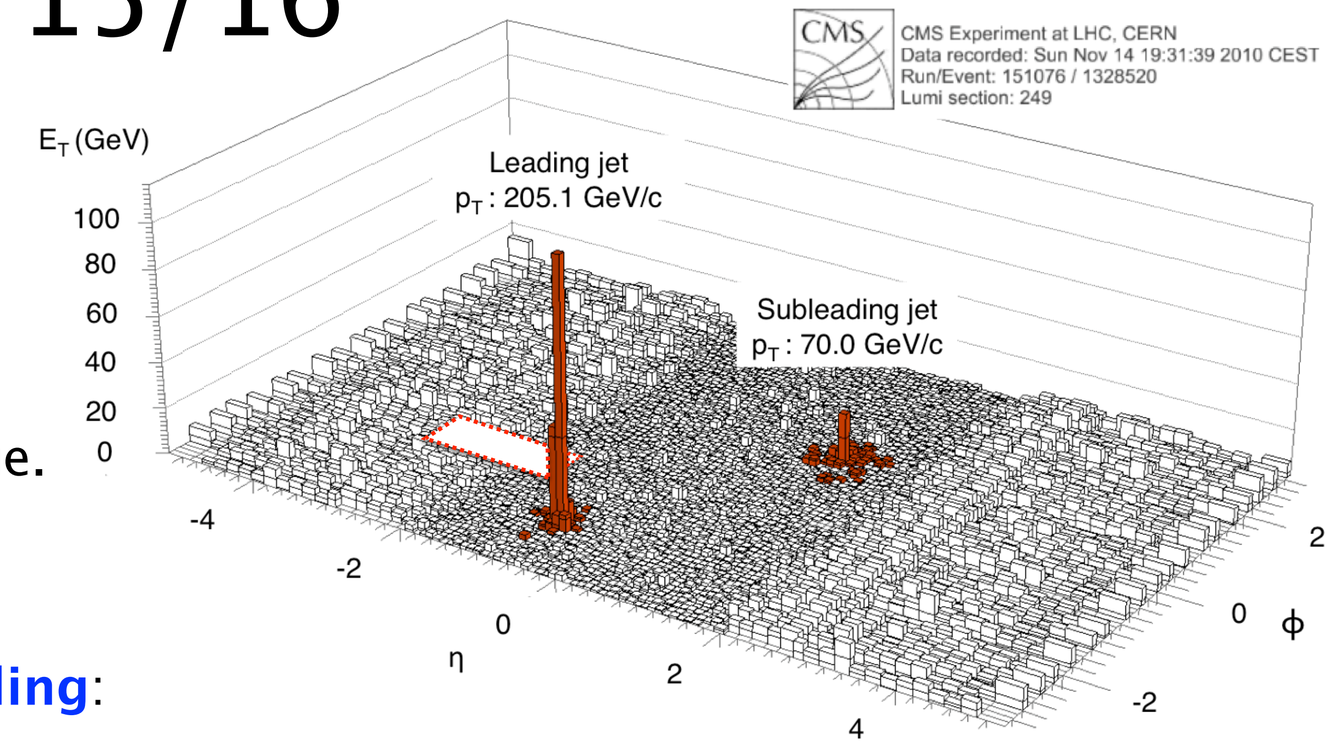


- Laser to Calibration Unit (CU)
  - HEP receives more light than HEM due to laser splitting.



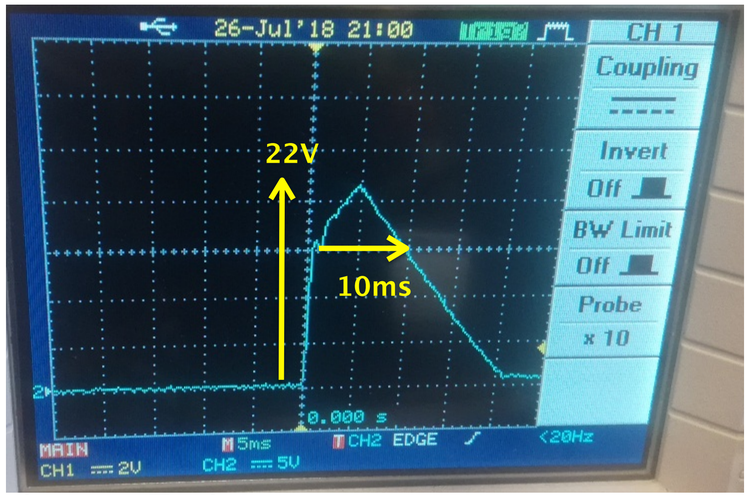
HCAL endcap sectors 15/16

Talk: CMS Status Report by Jim Hirschauer



- Following power interlock on June 30, **two endcap sectors are not functional**.
  - **40° in one endcap, 2% of HCAL** coverage.

- Five-week campaign led to **full understanding**:
  - On power up after interlock, 10V **power supply** (PS) **unable to read internal calibration**.
  - PS sent 22V/10ms pulse to detector
    - exceeded its own 14V max rating
    - **damaged on-detector components** with 12V rating.



HCAL endcap sectors 15/16 (cont'd)

- HCAL **installed secondary safety system** to mitigate risk of damage from potential future transients.

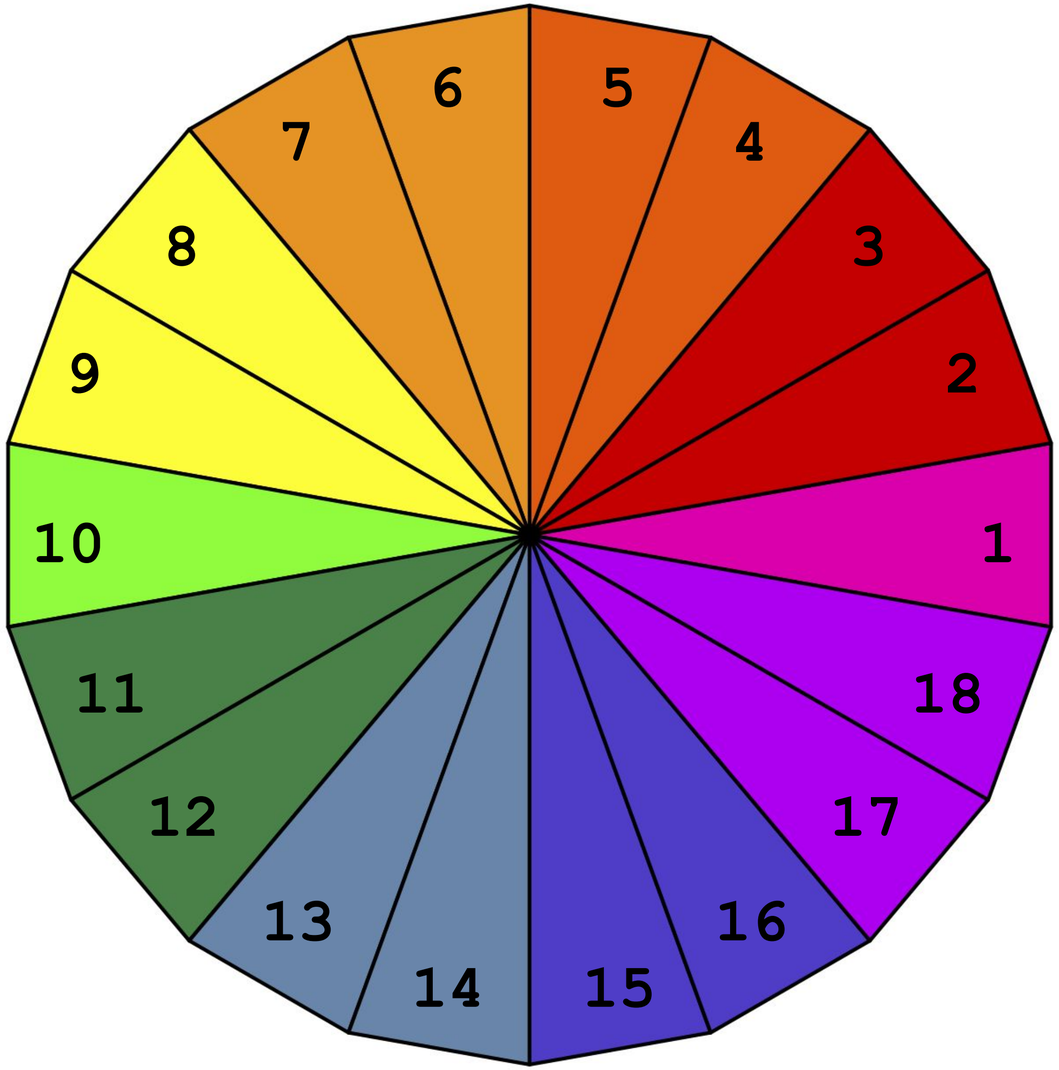
- **PS manufacturer** working to understand and address
  - why the PS fails to read its calibration
  - why the PS sends high voltage when the calibration fails

- **Physics impact:**
  - trigger rates are OK
  - effect on MET resolution is small but measureable
  - PF reconstruction reduces impact of loss.
  - Additional modifications of reconstruction in progress to minimize impact.

Talk: CMS Status Report by Jim Hirschauer

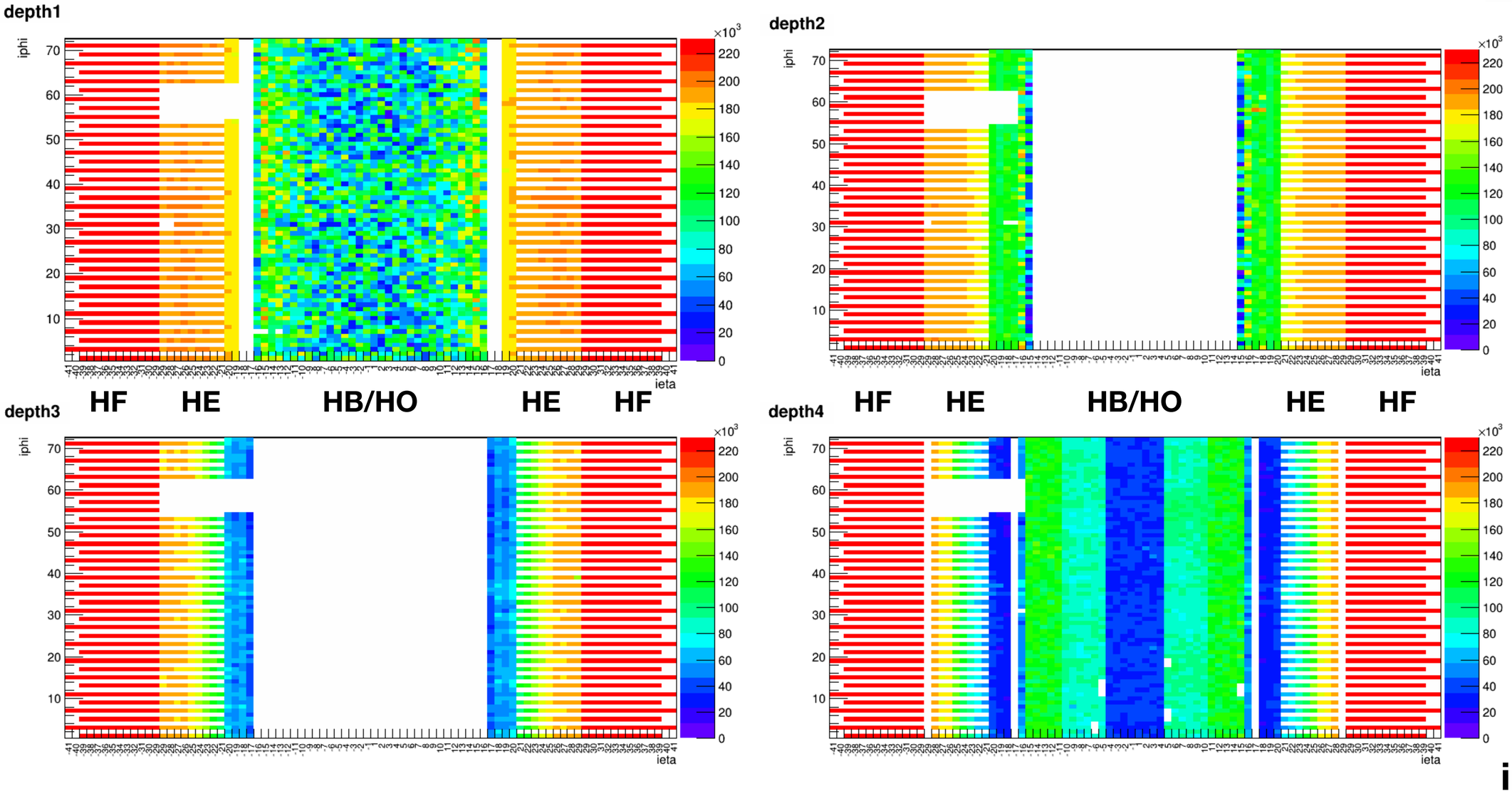
HCAL Endcap (HE)

- HCAL Endcap (HE)
- 18 wedges
  - 1 RBX per wedge
  - 20 deg. per wedge
- Colors correspond to power supplies
  - 1 or 2 RBX per power supply



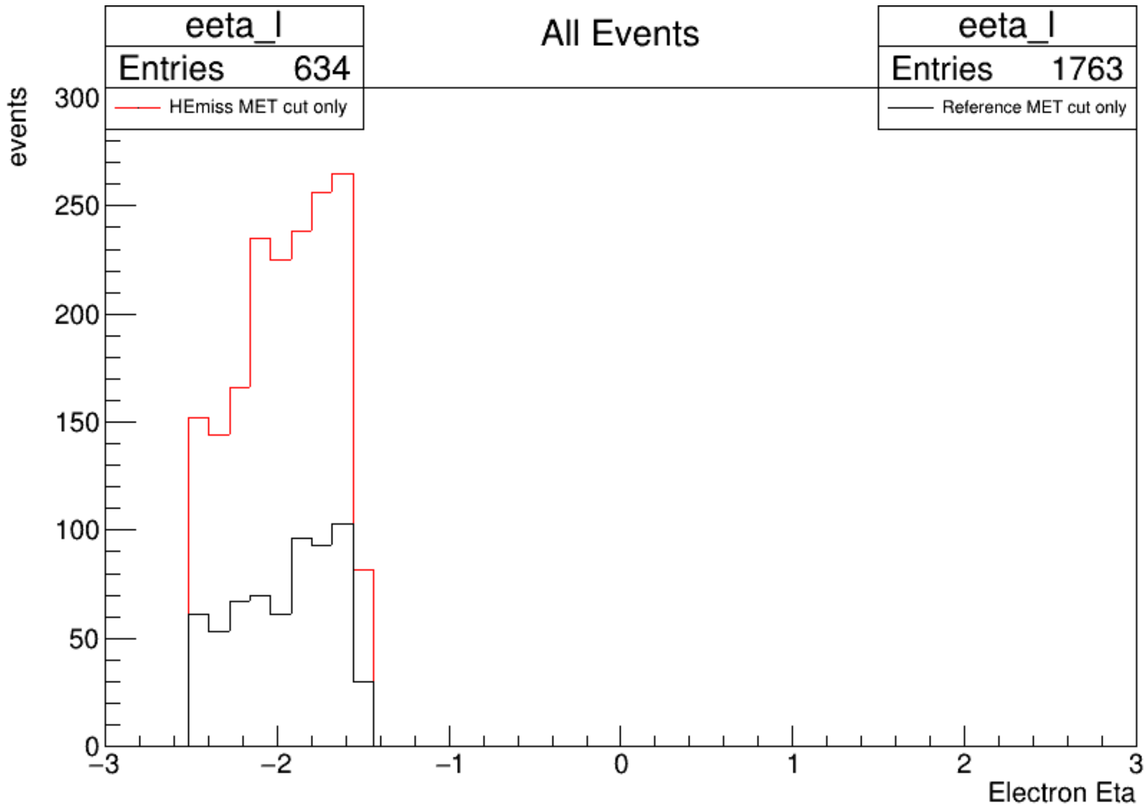
HCAL DQM

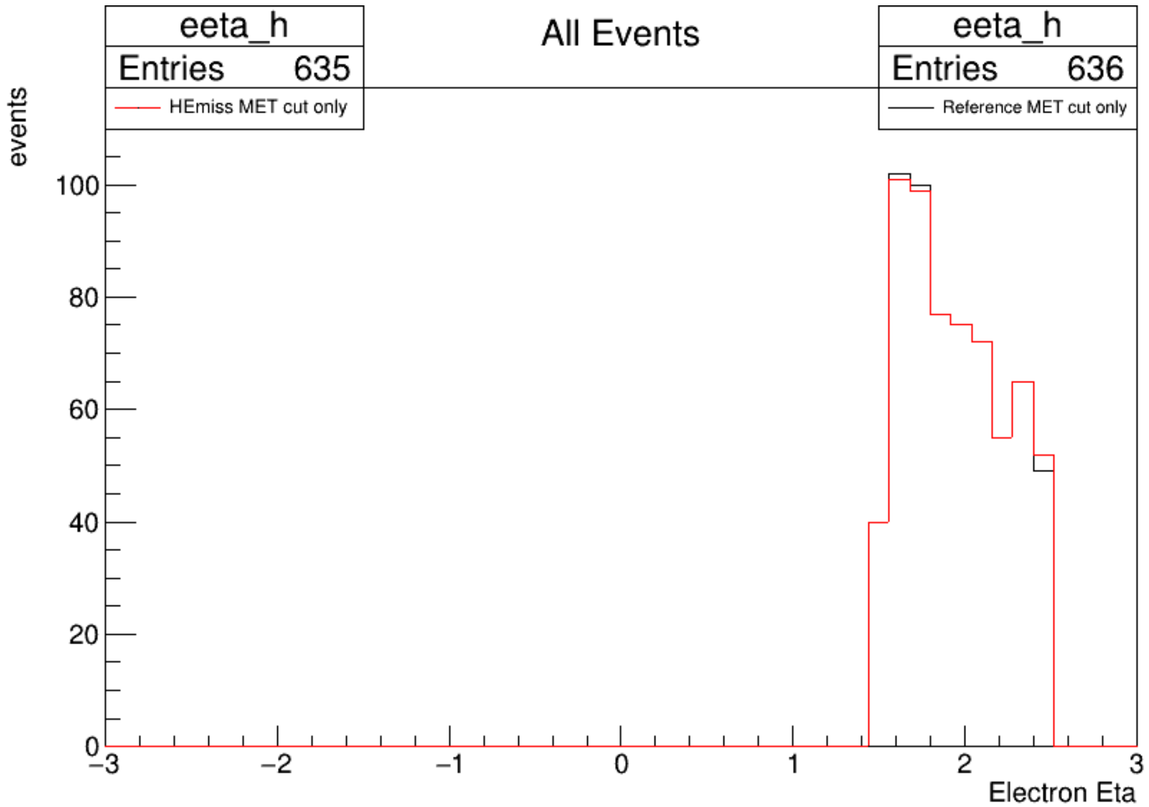
iφ



iη

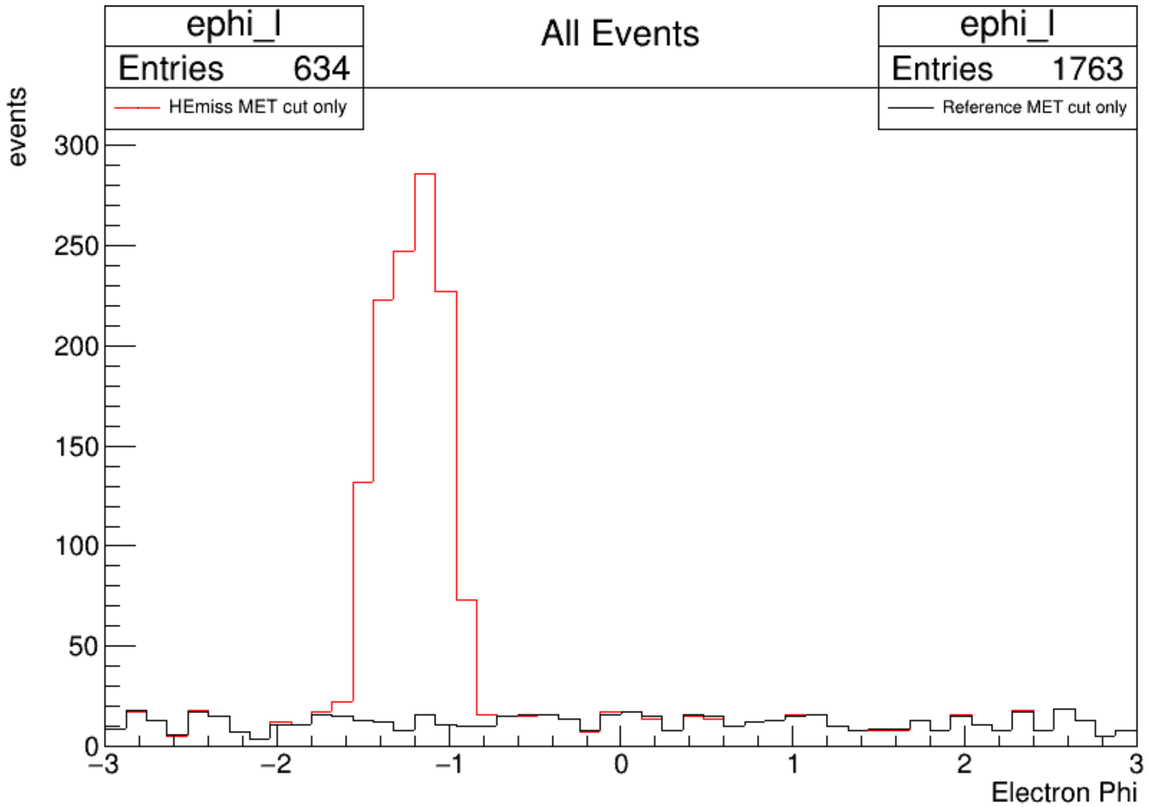
Electrons (η)

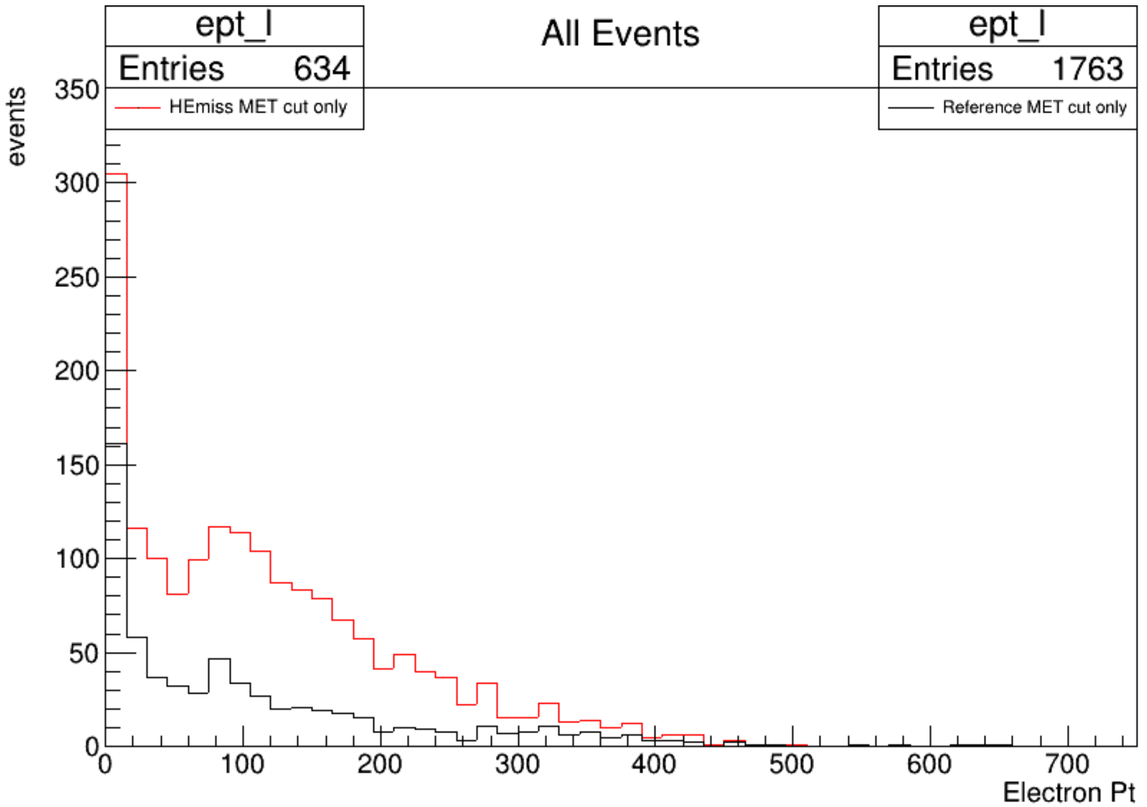




Talk: Check on HEM issue by Joe Pastika and Brooks McMaster

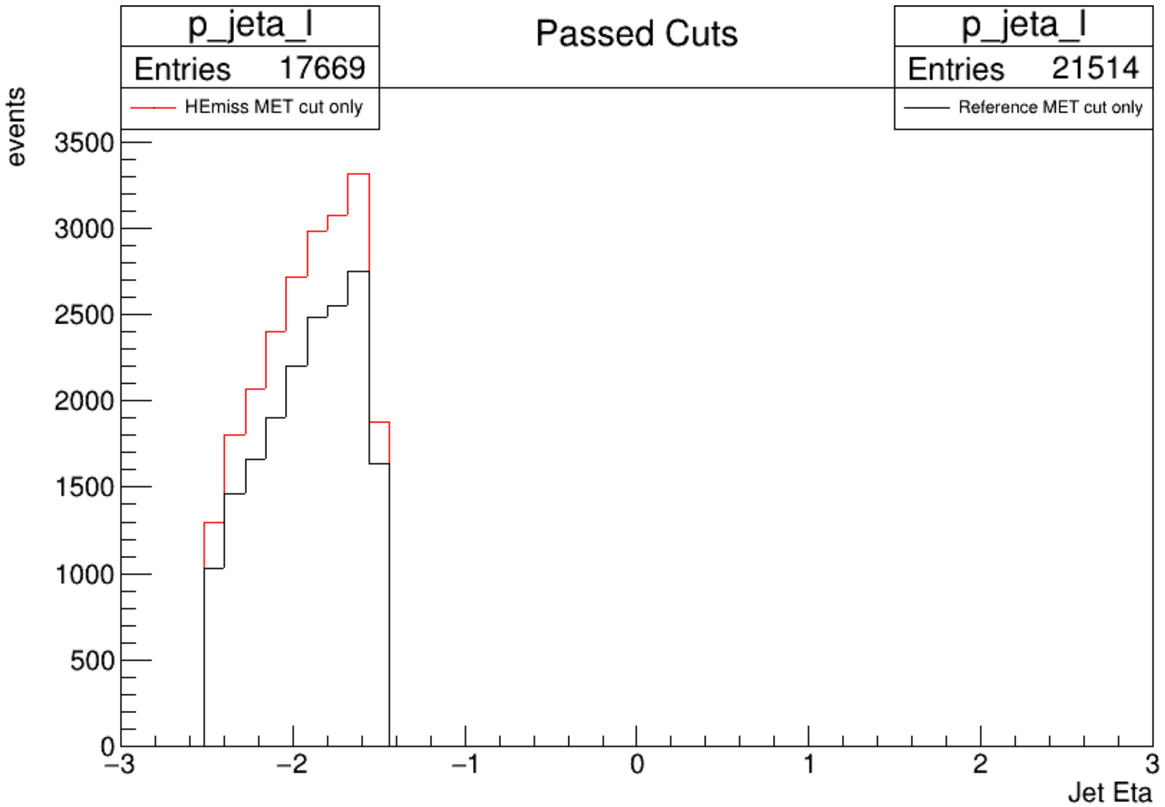
Electrons (ϕ, p_T)

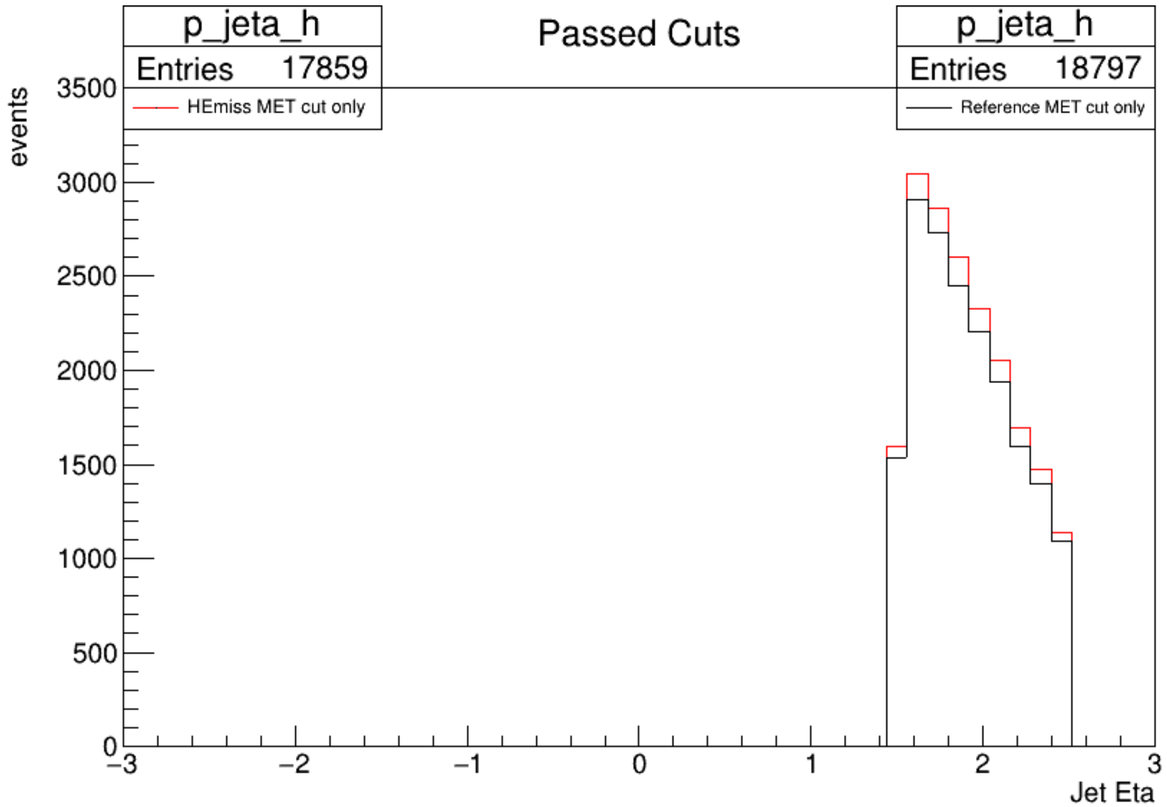




Talk: Check on HEM issue by Joe Pastika and Brooks McMaster

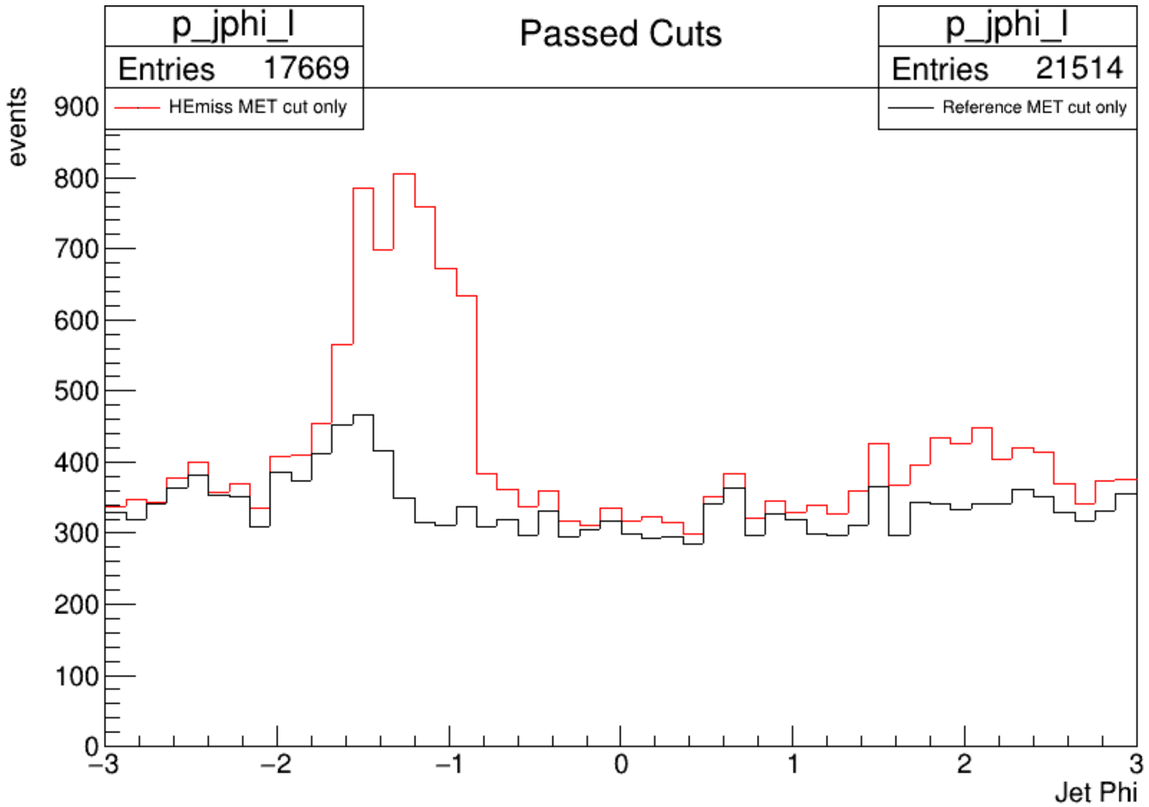
Jets (η)

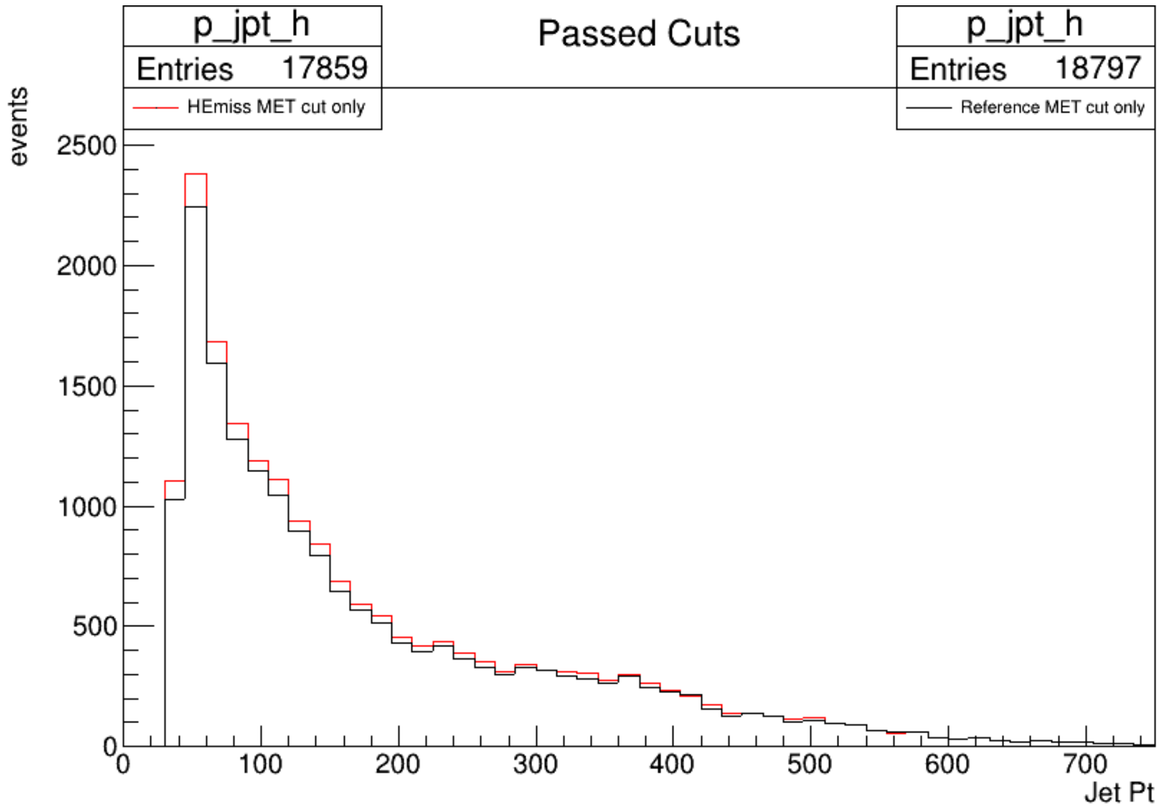




Talk: Check on HEM issue by Joe Pastika and Brooks McMaster

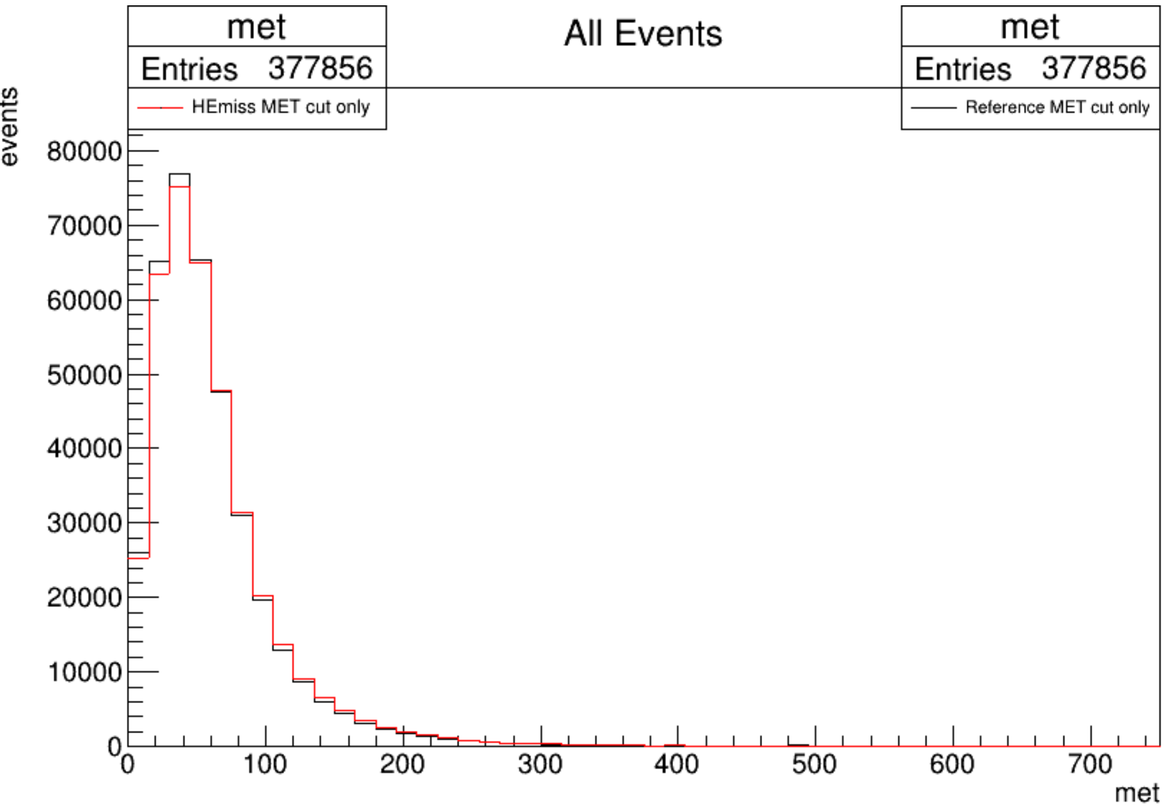
Jets (ϕ, p_T)

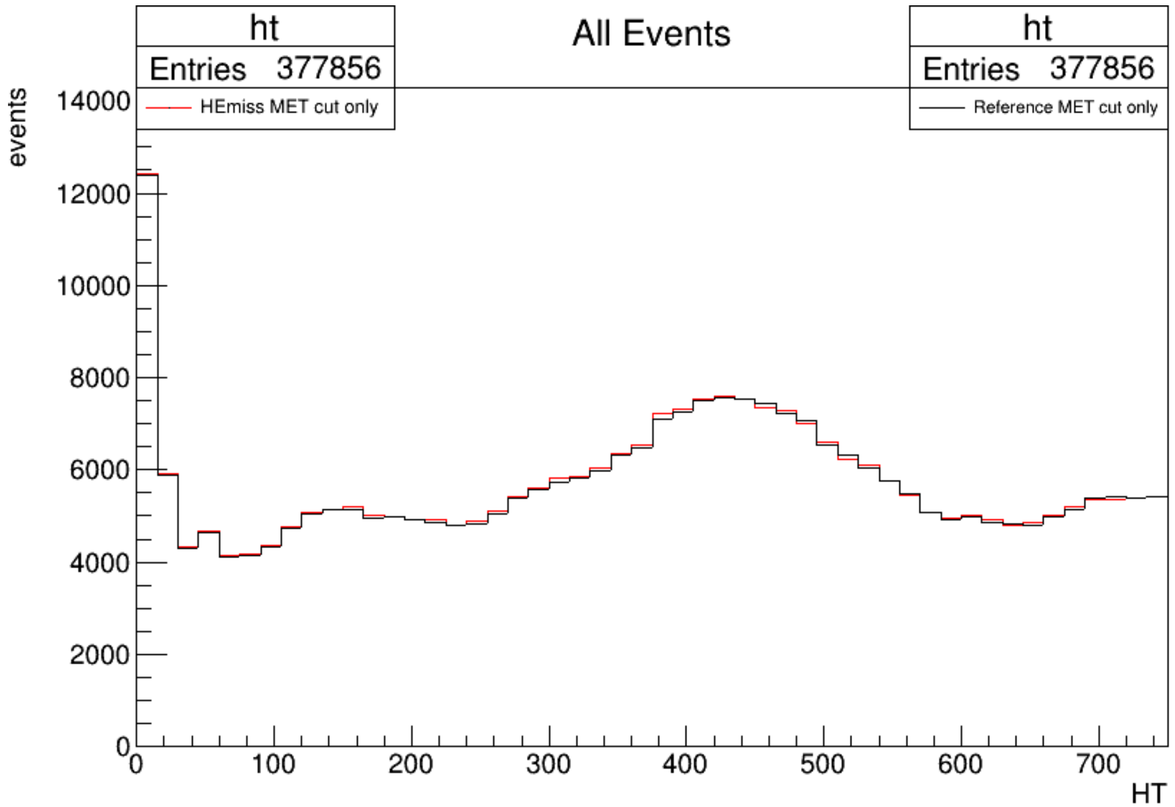




Talk: Check on HEM issue by Joe Pastika and Brooks McMaster

MET and H_T





Talk: Check on HEM issue by Joe Pastika and Brooks McMaster